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The Effect of Problem-Based Learning Integrated with Deep Learning on the Mathematical Reasoning Ability of Junior High School Students

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Research Article

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Abstract

This study aims to determine the effect of the Problem-Based Learning model integrated with Deep Learning on junior high school students' mathematical reasoning ability, as well as the level of improvement after the learning intervention. This research employed a quantitative approach using a quasi-experimental One-Group Pretest–Posttest design. The sample consisted of one class of junior high school students at SMP Negeri 1 Sinunukan, Mandailing Natal Regency, North Sumatra, Indonesia, who received Problem-Based Learning with a Deep Learning approach over four sessions. The research instrument was a mathematical reasoning test administered before and after the intervention. Data were analyzed using descriptive statistics, normality testing, paired sample t-test, and N-Gain analysis. The results show that the Problem-Based Learning model with Deep Learning has a significant effect on students' mathematical reasoning ability, indicated by a significance value of $p < 0.001$. Furthermore, the N-Gain analysis revealed a moderate-to-high level of improvement (mean N-Gain = 0.64). Thus, the Problem-Based Learning model integrated with Deep Learning is effective in enhancing students' mathematical reasoning ability.

1. Introduction

Education has undergone significant transformation in response to rapid developments in science, technology, and globalization. Modern educational systems are expected not only to transmit knowledge but also to equip students with the competencies necessary to adapt to increasingly complex social and professional environments (Destini, F., Syafridin, U., & Drupadi, R., 2026). Schools are therefore challenged to cultivate learners who can think independently, solve problems effectively, and make informed decisions based on evidence and logical reasoning. In this regard, mathematics education plays a crucial role because it provides students with opportunities to develop analytical thinking and systematic problem-solving abilities (Yuhana, Y., & Fajari, L. E. W., 2025). Mathematical learning experiences that emphasize understanding, reasoning, and application can help students become more competent in addressing real-world challenges. Consequently, the quality of mathematics instruction has become a major concern among educators and policymakers worldwide (Yapatang, L., & fon Polyiem, T., 2022). Educational innovations are continuously being explored to ensure that students acquire the skills required for success in the twenty-first century.

Mathematics is widely recognized as a discipline that contributes substantially to the development of logical thinking and intellectual growth. Through mathematics, students learn to analyse situations, identify patterns, formulate conjectures, and construct valid arguments based on evidence (Yang, S., & Berdine, G., 2021). These competencies are essential not only for academic achievement but also for everyday decision-making and professional practice (Muzakkir, M. A., 2021). However, despite the recognized importance of mathematics, many students continue to experience difficulties in understanding mathematical concepts and applying them to solve unfamiliar problems (Treepob, H., Hemtasin, C., & Thongsuk, T., 2023). Learning activities often focus heavily on procedural mastery and the memorization of formulas, leaving limited opportunities for students to engage in reasoning and conceptual exploration. As a result, students may achieve satisfactory computational performance while demonstrating weaknesses in higher-order thinking processes (Shongwe, B., 2024). This condition highlights the need for instructional approaches that promote deeper understanding and active knowledge construction.

Recent educational research has emphasized the importance of creating learning environments that encourage students to participate actively in the learning process. Student-centered approaches enable learners to investigate ideas, discuss alternative perspectives, and develop their understanding through meaningful interactions (Rindengan, R. F., & Wenas, R., 2020). Such approaches are particularly valuable in mathematics education because mathematical knowledge is most effectively acquired when students are engaged in exploration, inquiry, and reflection. Learning activities that involve authentic and challenging problems can stimulate curiosity and encourage students to apply mathematical concepts in meaningful contexts (Santos, J. M., 2017). Furthermore, collaborative learning experiences provide opportunities for students to articulate their thinking, justify their reasoning, and learn from the perspectives of their peers. These processes contribute to deeper conceptual understanding and support the development of critical thinking skills (Sari, Y. I., Sumarmi, Utomo, D. H., & Astina, I. K., 2021). Therefore, educational practices that emphasize active engagement and meaningful learning have become increasingly important in contemporary classrooms.

Among the instructional approaches that have gained considerable attention, Problem-Based Learning (PBL) has emerged as a promising strategy for promoting higher-order thinking and mathematical reasoning (Siregar, T., 2025). PBL engages students in solving authentic problems that require investigation, analysis, and collaborative decision-making (Rindengan, R. F., & Wenas, R., 2020). Through this approach, learners are encouraged to construct knowledge actively rather than passively receiving information from teachers. The integration of Deep Learning principles further enhances the effectiveness of PBL by emphasizing conceptual understanding, reflection, elaboration, and the meaningful connection of ideas (Santos, J. M., 2017). Students are guided to understand not only how mathematical procedures are performed but also why they are valid and applicable in different situations (Sari, Y. I., Sumarmi, Utomo, D. H., & Astina, I. K.,

2021). Consequently, the combination of PBL and Deep Learning has the potential to create rich learning experiences that foster reasoning, problem-solving, and long-term understanding. This instructional framework provides a strong foundation for improving students' mathematical competencies in today's increasingly complex educational landscape.

Twenty-first century education requires students to develop higher-order thinking skills, including critical, creative, communicative, and collaborative thinking, as well as the ability to reason in solving complex problems (OECD, 2019; Redhana, 2019). The Indonesian Merdeka Curriculum emphasizes the importance of student-centered learning oriented toward meaningful thinking processes, particularly mathematical reasoning as a fundamental competency needed to face global challenges (Kemendikbudristek, 2022). In the context of mathematics education, mathematical reasoning enables students not only to solve problems procedurally but also to construct logical arguments, analyse conceptual relationships, and draw valid conclusions across various situations (Putra & Yulanda, 2021; Rohmatulloh et al., 2022).

Despite its importance, previous studies indicate that Indonesian students' mathematical reasoning ability remains low. The 2022 PISA report highlights that Indonesian students' mathematical reasoning performance lags behind the OECD average (OECD, 2019). Research by Hasanah et al. (2023) also revealed that many students rely heavily on memorizing formulas rather than building conceptual understanding, which leads to difficulties in connecting mathematical ideas logically (Santos, J. M., 2017). This issue is exacerbated by instructional practices that still rely on teacher-centered approaches focused on lecturing and routine exercises without providing opportunities for students to construct knowledge independently (Fendrik, 2021). These conditions signal the need for more innovative instructional models that actively engage students, encourage deeper conceptual exploration, and support the development of structured mathematical reasoning. (Rindengan, R. F., & Wenas, R., 2020)

One relevant instructional model is Problem-Based Learning (PBL) (Siregar, T., 2023). This model positions contextual problems as the starting point of learning and provides opportunities for students to develop critical thinking, collaboration, and mathematical reasoning through exploration and problem-solving activities (Nurcahyaning Kusumawardani et al., 2022; Vatillah et al., 2020). Previous research has reported that PBL enhances student engagement, strengthens conceptual understanding, and significantly improves mathematical reasoning skills compared to conventional learning approaches (Sari, Y. I., Sumarmi, Utomo, D. H., & Astina, I. K., 2021). However, in practice, PBL implementation is often suboptimal. Many teachers emphasize problem-solving techniques rather than promoting reflective thinking and meaningful conceptual connections (Sulistiani & Lusiana, 2024). Therefore, strategies that can reinforce PBL are needed so that learning not only focuses on finding solutions but also on fostering deeper and more conscious thinking processes.

Deep Learning emerges as an approach that can strengthen the effectiveness of PBL. In the educational context, Deep Learning emphasizes meaningful, reflective, and profound learning experiences through cognitive, emotional, and experiential engagement (Mutmainnah et al., 2025). This approach encourages students not only to understand "how" a concept is applied but also "why" it is relevant and how various concepts are interrelated. Feriyanto & Anjariyah (2024) explain that Deep Learning is grounded in three principles: meaningful learning, mindful learning, and joyful learning; which support holistic and long-lasting conceptual understanding (Polat, H., & Özkaya, M., 2023). Thus, integrating PBL with Deep Learning has the potential to create learning experiences that not only guide students toward problem solving but also promote deeper awareness and conceptual reasoning.

The integration of PBL and Deep Learning is considered a comprehensive instructional approach that supports the development of mathematical reasoning. PBL provides authentic problem-solving experiences that require students to make conjectures, perform mathematical manipulations, and draw logical conclusions (Kusuma & Amelia, 2018). Meanwhile, Deep Learning reinforces these processes through reflection, conceptual linkage, and meaningful comprehension. According to Salmi et al. (2023), learning that combines problem solving with deep reflection leads to long-term understanding rather than short-term memorization. Through this integration, students are guided not only to find solutions but also to understand the underlying meaning of the strategies and mathematical concepts they employ.

Several relevant studies support the importance of this integration. Afifah et al. (2020) found that PBL significantly improves mathematical reasoning ability. Wahyudi (2025) reported that Deep Learning enhances students' reasoning and self-confidence in mathematics. Additionally, Ardhana et al. (2025) demonstrated that PBL integrated with Deep Learning significantly improves critical thinking skills. In this study, the integration of PBL and Deep Learning is implemented by positioning PBL as the instructional framework, while Deep Learning principles are embedded throughout each phase of the learning process.

Learning begins with contextual problems that require students to identify relevant information and formulate mathematical representations (meaningful learning). During group investigations, students are guided to analyze solution strategies, justify each step, and connect concepts logically (mindful learning). (Polat, H., & Özkaya, M., 2023) The learning process is completed with reflection and

discussion activities that encourage students to evaluate their reasoning and derive conceptual understanding (joyful learning). Through this integration, students are not only engaged in solving problems, but also in constructing meaning, reflecting on their thinking processes, and developing deeper conceptual understanding (Marchy, F., et al., 2022). However, research specifically examining the effect of PBL integrated with Deep Learning on junior high school students' mathematical reasoning remains limited. (Sari, Y. I., Sumarmi, Utomo, D. H., & Astina, I. K., 2021)

Based on this gap, the present study aims to investigate the effectiveness of PBL integrated with Deep Learning in improving junior high school students' mathematical reasoning ability at SMP Negeri 1 Sinunukan, Mandailing Natal Regency, North Sumatra, Indonesia. This study not only examines whether the model significantly influences mathematical reasoning but also analyses the extent of improvement after the instruction. Thus, this research is expected to contribute theoretically and practically to the development of mathematics instruction that is more meaningful, reflective, and oriented toward nurturing students' reasoning competencies.

2. Method

This study employed a quasi-experimental method using a One-Group Pretest–Posttest Design, in which a single group of students was given a pretest, followed by a learning intervention, and subsequently a posttest to examine the effect of the PBL integrated with Deep Learning model on students' mathematical reasoning ability. The research design is represented as $O_1 - X - O_2$, where O_1 denotes the pretest, X represents the instructional treatment, and O_2 represents the posttest.

The research sample consisted of one Grade VIII-A class at SMP Negeri 1 Sinunukan, Mandailing Natal Regency, North Sumatra, Indonesia in the 2025/2026 academic year, selected through purposive sampling based on the class's readiness, stability of the number of students, and suitability of the mathematics instructional schedule. The number of students in the class was 30, with ages between 13 and 15 years. All research activities were conducted during regular mathematics lessons. Figure 1 illustrates the research design.

Pretest (**O_1**) → Intervention (**X: PBL + Deep Learning, 4 sessions**) → Posttest (**O_2**)

The research instruments consisted of a mathematical reasoning test and instructional materials developed based on the PBL and Deep Learning approaches. The test comprised five open-ended items constructed according to mathematical reasoning indicators, including: (1) ability to understand problems, (2) ability to formulate mathematical models, (3) ability to conduct systematic solution procedures, (4) ability to provide logical justifications, and (5) ability to draw conclusions. Each item was scored using an analytic rubric ranging from 0 to 4, where a score of 0 indicated no response or irrelevant answers, and a score of 4 indicated a complete and correct solution accompanied by logical reasoning and appropriate conclusions. The mapping between test items and reasoning indicators was as follows: item 1 assessed the ability to understand the problem; item 2 assessed the ability to formulate mathematical models; item 3 assessed systematic solution procedures; item 4 measured logical justification of solutions; and item 5 evaluated the ability to draw mathematical conclusions. The test was administered as both a pretest and posttest using equivalent forms. The instrument underwent expert validation and empirical testing, including examinations of validity, reliability, discrimination power, and difficulty index, ensuring that the assessment met the criteria for a high-quality instrument.

The instructional treatment was implemented over four sessions. The PBL with Deep Learning approach began with presenting contextual Systems of Linear Equations in Two Variables (SPLDV) problems that required students to identify key information, formulate mathematical representations, and select appropriate solution strategies. Students worked collaboratively in groups to investigate the problem, connect relevant concepts, analyse solution steps, and reflect on their chosen strategies. The learning activities proceeded with group presentations and intergroup discussions, which further strengthened students' mathematical reasoning processes and deepened their conceptual understanding. (Martaningsih, S.T., et al., 2022)

Data from the pretest and posttest were analysed descriptively to obtain the minimum, maximum, mean, and standard deviation values. Furthermore, the Kolmogorov–Smirnov normality test was conducted to determine the appropriate statistical analysis. Because the difference scores between the pretest and posttest were normally distributed, a paired sample t-test was used to examine whether significant differences existed before and after the intervention. In addition, the N-Gain score was calculated to determine the level of improvement in students' mathematical reasoning ability, categorized into low ($g < 0.3$), medium ($0.3 \leq g \leq 0.7$), or high ($g > 0.7$) improvement.

3. Results and Discussion

3.1 Results

The results of the study indicate an improvement in students' mathematical reasoning ability after the implementation of the PBL integrated with Deep Learning model. The descriptive analysis of the pretest scores is presented in Table 1.

Table 1
Descriptive Statistics of Pretest Mathematical Reasoning Ability

Statistic	Value
Number of Students	30
Minimum Score	20
Maximum Score	68
Mean	41.73
Standard Deviation	12.387

Based on Table 1, students' initial mathematical reasoning ability was in the low-to-medium category. The mean score of 41.73 indicates that most students had not yet mastered Systems of Linear Equations in Two Variables concepts nor reasoning indicators such as providing logical explanations, constructing arguments, and drawing conclusions. The minimum score of 20 indicates that some students were only able to answer a small portion of the test items and showed limited understanding of the problem context and reasoning processes. In contrast, the maximum score of 68 suggests that a small number of students were able to demonstrate partial mastery of the concepts and reasoning indicators, although their understanding was not yet optimal. These results indicate that students' initial mathematical reasoning ability varied considerably prior to the intervention.

To the relatively low mean score, the standard deviation of 12.387 indicates a considerable variation in students' initial mathematical reasoning ability. This finding suggests that students entered the study with diverse levels of understanding and reasoning competence. While a small number of students demonstrated a moderate ability to analyse problems and formulate mathematical arguments, many others experienced difficulties in interpreting problem situations and selecting appropriate solution strategies (McLeod, S. A., 2016). The wide range between the minimum score of 20 and the maximum score of 68 further confirms the existence of substantial differences in students' prior knowledge and reasoning skills. Such variation is common in mathematics classrooms where students possess different learning experiences, levels of conceptual understanding, and problem-solving backgrounds (Martaningsih, S.T., et al., 2022). Consequently, the pretest results highlight the need for instructional approaches capable of accommodating these differences while simultaneously promoting the development of higher-order thinking skills. Understanding students' initial conditions is important because it provides a baseline for evaluating the effectiveness of the learning intervention implemented during the study.

The low pretest performance suggests that traditional learning experiences prior to the intervention may not have sufficiently supported the development of mathematical reasoning (Martaningsih, S.T., et al., 2022). Many students appeared to rely primarily on procedural knowledge and memorized formulas rather than engaging in analytical thinking and logical justification. This tendency may explain why several students struggled to provide coherent explanations, construct mathematical arguments, and draw valid conclusions from the given problems (McLeod, S. A., 2016). The findings indicate that students required learning experiences that actively involve them in exploring concepts, discussing ideas, and reflecting on their reasoning processes. Such needs are consistent with contemporary mathematics education goals, which emphasize understanding, reasoning, and problem-solving rather than mere computational proficiency (Muzakkir, M. A., 2021). Therefore, the pretest results not only reveal students' initial weaknesses but also provide a strong rationale for implementing Problem-Based Learning integrated with Deep Learning principles as an instructional strategy to improve mathematical reasoning ability. The relatively low starting point also makes it possible to observe more clearly the extent of learning gains achieved following the intervention.

Normality testing confirmed that the pretest data were normally distributed. The Kolmogorov–Smirnov results are presented in Table 2.

Table 2
Normality Test of Pretest Scores

Data	Statistic	df	Sig.	Conclusion
Pretest	0.131	30	0.200	Normal

The significance value of 0.200 > 0.05 indicates that the data met the normality assumption, allowing further parametric testing.

After the implementation of PBL integrated with Deep Learning, students' abilities increased considerably. The descriptive statistics of the posttest scores are displayed in Table 3.

Table 3
Descriptive Statistics of Posttest Mathematical Reasoning Ability

Statistic	Value
Number of Students	30
Minimum Score	62
Maximum Score	96
Mean	79.40
Standard Deviation	9.873

Table 3 shows significant improvement across all parameters. The mean score increased from 41.73 to 79.40, nearly doubling. The minimum score of 62 indicates that all students were able to demonstrate basic to adequate levels of mathematical reasoning, including understanding the problem context, applying appropriate solution strategies, and providing logical justifications. The maximum score of 96 suggests that some students achieved near-complete mastery of the mathematical reasoning indicators assessed, including systematic problem-solving and accurate conclusions (McLeod, S. A., 2016). The reduced standard deviation (9.873) suggests improved equity in student performance following the learning treatment. Furthermore, the increase in posttest scores cannot be attributed solely to students' prior exposure to similar test items in the pretest, as the pretest and posttest employed equivalent forms with different problem contexts and numerical values. Therefore, the observed improvement reflects genuine development in students' mathematical reasoning ability resulting from the learning intervention rather than a test familiarity effect.

The substantial increase in the mean score from 41.73 in the pretest to 79.40 in the posttest demonstrates that the learning intervention had a strong positive impact on students' mathematical reasoning ability. This improvement indicates that students became more proficient in interpreting mathematical problems, identifying relevant information, selecting appropriate strategies, and constructing logical arguments to support their solutions. The relatively high posttest mean suggests that most students were able to achieve a satisfactory level of mastery of the reasoning indicators assessed during the study. Moreover, the increase in performance reflects not only improvements in procedural competence but also gains in conceptual understanding and analytical thinking. Students appeared more capable of connecting mathematical concepts, evaluating alternative approaches, and drawing valid conclusions based on available evidence (Muzakkir, M. A., 2021). Such outcomes are consistent with the objectives of Problem-Based Learning integrated with Deep Learning principles, which emphasize meaningful engagement, critical analysis, and reflective thinking. Therefore, the posttest results provide strong evidence that the instructional approach successfully enhanced students' mathematical reasoning competencies.

In addition to the improvement in average achievement, the distribution of posttest scores reveals positive developments in overall student performance. The minimum score of 62 indicates that even the lowest-performing students were able to demonstrate a reasonable level of mathematical reasoning after participating in the intervention. At the same time, the maximum score of 96 reflects the ability of several students to perform at an exceptionally high level, demonstrating comprehensive understanding, systematic reasoning, and accurate problem-solving skills. The reduction in score variability, as reflected by the standard deviation of 9.873, suggests that learning gains were experienced by students across different achievement levels rather than being concentrated among only a few high-performing individuals. This finding indicates that the instructional treatment contributed not only to improving achievement but also to promoting greater equity in learning outcomes. Furthermore, because the posttest consisted of equivalent items with different contexts and numerical values, the observed gains cannot be explained merely by familiarity with the assessment format. Instead, the results indicate genuine cognitive growth and enhanced reasoning ability, suggesting that students developed transferable mathematical understanding that could be applied to new and unfamiliar problem situations. The posttest data also met the normality assumption, as shown in Table 4.

Table 4
Normality Test of Posttest Scores

Data	Statistic	df	Sig.	Conclusion
Posttest	0.124	30	0.254	Normal

Since both pretest and posttest scores were normally distributed, a paired sample t-test was used for further analysis. The results are shown in Table 5.

Table 5
Paired Sample t-Test Results

Statistic	Value
df	29
p-value	< 0.001
Mean Difference	37.67
SE Difference	11.420
t-value	18.063

The p-value < 0.001 indicates a statistically significant difference between pretest and posttest scores, confirming that the PBL with Deep Learning approach had a significant effect on improving students' mathematical reasoning ability.

The magnitude of improvement was further examined using the N-Gain score, presented in Table 6.

Table 6
N-Gain Score Analysis

Statistic	Value
N-Gain Minimum	0.45
N-Gain Maximum	0.88
Mean N-Gain	0.64
Category	**Medium-High**

The mean N-Gain score of 0.64 indicates that the improvement in mathematical reasoning was in the medium-to-high category. This suggests that the intervention was not only statistically significant but also practically effective.

3.2 Discussion

The observed improvement aligns with the characteristics of PBL, which engages students in analysing authentic problems, identifying essential information, establishing relationships between concepts, and developing mathematical justifications (Nasution, M. S., et al., 2026). The integration of Deep Learning strengthened these processes by fostering deep thinking, elaboration of ideas, and reflection on solution strategies (Sutama, et al., 2026). Students were not merely solving problems, but also understanding the logical rationale behind each step.

In the PBL approach, students are encouraged to analyse complex situations that resemble real-life contexts, requiring them to identify relevant information and determine appropriate strategies for solving problems. This learning process stimulates active participation because students are not merely receiving information from the teacher but are constructing their own understanding through investigation and discussion (Anugraheni, I., Gufron, A., & Purnomo, Y. W., 2025). As students work collaboratively to solve problems, they develop the ability to identify patterns, evaluate alternative solutions, and justify their reasoning using mathematical concepts. Such activities contribute significantly to the development of higher-order thinking skills, particularly mathematical reasoning (Fardian, D., & Dasari, D., 2023). Furthermore, the authentic nature of the problems enhances students' motivation because they can see the relevance of mathematics to everyday situations. Consequently, students become more engaged in learning and demonstrate a deeper understanding of mathematical concepts. (Sutama, et al., 2026)

The improvement in students' mathematical reasoning ability can also be attributed to the emphasis of PBL on conceptual connections. During the learning process, students are required to establish relationships among various mathematical ideas rather than treating concepts as isolated pieces of information (Fardian, D., & Dasari, D., 2023). Through guided inquiry and problem-solving activities, learners discover how different mathematical principles interact and support one another in finding solutions. This process encourages students to move beyond procedural knowledge and develop a more integrated understanding of mathematics (Sutama, et al., 2026). As students continuously connect prior knowledge with newly acquired information, their cognitive structures become more organized and meaningful. Such meaningful learning experiences facilitate knowledge retention and transfer to new situations (Dewi, D. V., Triwahyuni, E., & Kustiyowati, 2025). Moreover, students become increasingly capable of explaining their reasoning and defending their conclusions using

logical arguments (Anugraheni, I., Gufron, A., & Purnomo, Y. W., 2025). Therefore, the PBL model provides an effective framework for nurturing mathematical reasoning and conceptual understanding simultaneously.

The integration of Deep Learning further strengthened the effectiveness of PBL by encouraging students to engage in deeper cognitive processes throughout the learning experience. Deep Learning emphasizes meaningful understanding, critical reflection, and active knowledge construction rather than rote memorization (Fardian, D., & Dasari, D., 2023). In this learning environment, students are encouraged to explore the underlying principles of mathematical concepts and examine why specific procedures or formulas work. Such an approach promotes intellectual curiosity and motivates students to investigate mathematical ideas more thoroughly (Hallinger, P., & Nguyen, V.-T., 2020). Students become more willing to question assumptions, evaluate evidence, and explore multiple solution pathways (Anugraheni, I., Gufron, A., & Purnomo, Y. W., 2025). This deeper engagement allows learners to develop a richer understanding of mathematical relationships and structures. As a result, students are not only able to solve mathematical problems accurately but also understand the reasoning that supports their solutions.

Another important contribution of Deep Learning lies in its emphasis on elaboration and reflection. During the learning activities, students are encouraged to elaborate on their ideas by providing detailed explanations, examples, and justifications for their mathematical thinking (Dewi, D. V., Triwahyuni, E., & Kustiyowati, 2025). This process helps students clarify their understanding and identify potential misconceptions that may hinder their learning. Reflection activities further enhance cognitive development by allowing students to evaluate the effectiveness of their problem-solving strategies and consider alternative approaches (Ayari, M. A., et al., 2025). Through reflective thinking, learners become more aware of their own learning processes and develop metacognitive skills that support independent learning (Hallinger, P., & Nguyen, V.-T., 2020). These reflective practices enable students to recognize strengths and weaknesses in their reasoning and make necessary adjustments for future problem-solving tasks. Consequently, students become more strategic, confident, and flexible in applying mathematical concepts to different contexts. Such characteristics are essential components of strong mathematical reasoning ability.

The combination of PBL and Deep Learning creates a synergistic learning environment that promotes meaningful and sustainable learning outcomes. While PBL provides authentic problems that stimulate inquiry and collaboration, Deep Learning ensures that students engage with these problems at a profound cognitive level. Together, these approaches encourage students to analyse, evaluate, and create knowledge rather than simply remember information (Ayari, M. A., et al., 2025). Students are challenged to justify each step of their reasoning, communicate their ideas effectively, and critically examine the validity of their solutions (Hallinger, P., & Nguyen, V.-T., 2020). This comprehensive learning process supports the development of logical thinking, analytical reasoning, and problem-solving skills (Laine, C. E., & Mahmud, M. S., 2022). The findings suggest that students were not merely focused on obtaining correct answers but were actively constructing a deep understanding of mathematical concepts and procedures. Therefore, the integration of PBL and Deep Learning represents a powerful instructional approach for enhancing students' mathematical reasoning ability and fostering lifelong learning competencies.

These findings are consistent with Glazewski & Hmelo-Silver (2019), who reported that PBL enhances higher-order thinking through investigative and argumentative activities when dealing with complex problems. Similarly, Savery (2015) found that PBL encourages students to build conceptual connections and reinforce mathematical reasoning through discussion and reflection. In line with this, Ashari (2024) noted that problem-based instruction significantly improves mathematical reasoning because students engage in analytical processes required to comprehend the structure of mathematical tasks. (Ayari, M. A., et al., 2025)

The findings of this study are consistent with previous research highlighting the effectiveness of Problem-Based Learning (PBL) in developing students' higher-order thinking skills and mathematical reasoning abilities (Laine, C. E., & Mahmud, M. S., 2022). The significant improvement observed among students who participated in PBL integrated with Deep Learning supports the notion that meaningful engagement with authentic problems can facilitate deeper cognitive development. Through problem-solving activities, students are required to investigate situations, analyse available information, formulate hypotheses, and construct logical arguments to support their solutions (Barana, A., Marchisio, M., & Miori, R., 2019). These processes naturally encourage learners to move beyond memorization and engage in complex thinking activities. As a result, students become more capable of interpreting mathematical situations and applying appropriate reasoning strategies (Hallinger, P., & Nguyen, V.-T., 2020). The findings indicate that the learning environment created through PBL provides opportunities for students to actively construct knowledge while developing critical thinking skills. Such outcomes are particularly important in mathematics education, where reasoning and problem-solving are fundamental competencies. (Dewi, D. V., Triwahyuni, E., & Kustiyowati, 2025)

The results align with the work of Glazewski and Hmelo-Silver (2019), who reported that PBL enhances higher-order thinking through investigative and argumentative activities when students are confronted with complex and authentic problems. According to their findings,

the process of exploring multiple perspectives and evaluating alternative solutions encourages learners to engage in deeper levels of cognitive processing (Barana, A., Marchisio, M., & Miori, R., 2019). Students participating in PBL are not passive recipients of information; rather, they actively investigate problems, collect evidence, and formulate reasoned conclusions. Such investigative activities require learners to analyse information critically and justify their decisions using logical arguments (Dahal, P. P., & G.C., L., 2026). These experiences contribute directly to the development of reasoning abilities because students continuously evaluate the validity of their assumptions and conclusions (Pramasdyahsari, A. S., et al., 2023). Furthermore, argumentative discussions within collaborative learning groups allow students to defend their ideas while considering alternative viewpoints presented by their peers. Consequently, the learning process becomes an intellectual exercise that strengthens analytical and reasoning skills. (Laine, C. E., & Mahmud, M. S., 2022)

The present findings are also supported by the work of Howard S. Barrows Savery (2015), who found that PBL encourages students to build conceptual connections and reinforce mathematical reasoning through discussion and reflection. One of the primary strengths of PBL lies in its capacity to connect new knowledge with students' existing cognitive frameworks (Barana, A., Marchisio, M., & Miori, R., 2019). During problem-solving activities, students must identify relationships among concepts and determine how different mathematical principles can be applied to address a given problem. Through collaborative discussions, learners exchange ideas, compare solution strategies, and evaluate the effectiveness of various approaches (Hallinger, P., & Nguyen, V.-T., 2020). These interactions help students develop a more integrated understanding of mathematical concepts rather than viewing them as isolated procedures. Reflection activities further strengthen this understanding by encouraging students to revisit their reasoning processes and evaluate the logic behind their solutions. As a result, students develop deeper conceptual understanding and stronger mathematical reasoning skills. (Laine, C. E., & Mahmud, M. S., 2022)

The findings are consistent with the study conducted by Ashari (2024), which demonstrated that problem-based instruction significantly improves mathematical reasoning because students are actively involved in analytical processes required to understand the structure of mathematical tasks (Pramasdyahsari, A. S., et al., 2023). Mathematical reasoning develops when students are challenged to interpret problems, identify relevant information, and determine appropriate solution strategies (Samosir, C. M., Muhammad, I., Marchy, F., & Elmawati, E., 2023). Problem-based instruction provides numerous opportunities for such analytical engagement by presenting students with non-routine tasks that require careful examination and logical thinking. Rather than relying on memorized procedures, students must understand the underlying mathematical concepts and relationships involved in each problem (Suseelan, M., Chew, C. M., & Chin, H., 2022). This analytical engagement promotes a deeper comprehension of mathematical structures and enhances students' ability to formulate coherent and logical arguments. Consequently, students become more proficient in explaining their reasoning and justifying their conclusions based on mathematical evidence.

Taken together, the findings from the current study and previous research provide strong evidence that PBL serves as an effective pedagogical approach for developing mathematical reasoning and higher-order thinking skills. The consistent results across multiple studies suggest that the benefits of PBL arise from its emphasis on inquiry, collaboration, reflection, and conceptual understanding (Samosir, C. M., Muhammad, I., Marchy, F., & Elmawati, E., 2023). By engaging students in investigative activities, encouraging discussion and argumentation, and fostering reflective thinking, PBL creates a learning environment that supports meaningful knowledge construction (Suseelan, M., Chew, C. M., & Chin, H., 2022). The integration of Deep Learning principles further amplifies these benefits by promoting deeper cognitive engagement and encouraging students to understand the rationale behind mathematical procedures. Therefore, the convergence of evidence from the studies of Glazewski and Hmelo-Silver (2019), Savery (2015), Ashari (2024), and the present research reinforces the conclusion that PBL is a powerful instructional model for enhancing students' mathematical reasoning abilities and preparing them for complex problem-solving situations in academic and real-world contexts. (Pramasdyahsari, A. S., et al., 2023)

Problem-Based Learning (PBL) is an effective instructional approach for fostering students' mathematical reasoning and higher-order thinking skills (Suseelan, M., Chew, C. M., & Chin, H., 2022). The consistency of findings across different educational settings and student populations indicates that the positive effects of PBL are not isolated phenomena but rather reflect the inherent strengths of the model itself. By placing students in situations where they must actively investigate problems, analyse information, and construct solutions, PBL creates opportunities for meaningful intellectual engagement (Taufik, Nurtamam, M. E., Dewanto, & Santosa, T. A., 2025). Unlike traditional teacher-centred approaches that often emphasize the transmission of knowledge, PBL encourages learners to take an active role in their own learning processes (Aba-Oli, Z., Koyas, K., & Husen, A., 2025). This active engagement enables students to develop deeper conceptual understanding and stronger reasoning abilities. Consequently, students become more capable of applying mathematical concepts flexibly and effectively in various contexts. Such outcomes are particularly valuable in contemporary education, where critical thinking and problem-solving skills are increasingly recognized as essential competencies. (Samosir, C. M., Muhammad, I., Marchy, F., & Elmawati, E., 2023)

One of the primary reasons for the effectiveness of PBL lies in its emphasis on inquiry-based learning. Through inquiry activities, students are encouraged to formulate questions, explore possible explanations, gather relevant information, and evaluate evidence before reaching conclusions (Putri, O. R. U., Susiswo, Hidayanto, E., & Slamet, 2023). These processes require learners to engage in analytical and critical thinking rather than simply recalling information from memory (Amallya, E., Anggoro, B. S., and Fadila, A., 2025). In mathematics education, inquiry-based learning helps students understand not only how mathematical procedures are performed but also why those procedures are valid and useful. As students investigate mathematical problems independently and collaboratively, they develop the ability to recognize patterns, establish relationships, and construct logical arguments (Suseelan, M., Chew, C. M., & Chin, H., 2022). This deeper level of engagement promotes meaningful learning experiences that contribute to long-term knowledge retention. Furthermore, inquiry-based activities help students become more confident in their ability to solve unfamiliar problems. Therefore, inquiry serves as a fundamental mechanism through which PBL enhances mathematical reasoning and cognitive development.

Collaboration represents another essential component that contributes to the success of PBL. During collaborative problem-solving activities, students have opportunities to exchange ideas, discuss alternative perspectives, and evaluate different solution strategies (Yusuf, A. R., Marji, Sutadji, E., & Sugandi, M., 2023). These interactions encourage learners to articulate their reasoning clearly and justify their conclusions using mathematical evidence. Through dialogue and argumentation, students are exposed to diverse ways of thinking, which broadens their understanding of mathematical concepts and problem-solving approaches. Collaborative learning also promotes social construction of knowledge, where understanding is developed through interaction and shared experiences (Taufik, Nurtamam, M. E., Dewanto, & Santosa, T. A., 2025). As students negotiate meaning and challenge one another's assumptions, they refine their reasoning and strengthen their conceptual understanding. Moreover, collaborative environments foster communication skills that are critical for academic success and professional development. Thus, the collaborative nature of PBL significantly contributes to the enhancement of mathematical reasoning abilities. (Putri, O. R. U., Susiswo, Hidayanto, E., & Slamet, 2023)

Reflection is equally important in explaining the effectiveness of PBL. Reflective activities encourage students to examine their learning processes, evaluate the effectiveness of their strategies, and identify areas for improvement. Through reflection, learners become more aware of how they think, learn, and solve problems, leading to the development of metacognitive skills (Yusuf, A. R., Marji, Sutadji, E., & Sugandi, M., 2023). These skills enable students to monitor their understanding, recognize misconceptions, and make adjustments when necessary. In mathematics, reflective thinking helps students evaluate the validity of their reasoning and consider alternative methods for approaching problems. This continuous process of self-assessment and improvement supports deeper understanding and more effective problem-solving performance. Reflection also encourages students to connect newly acquired knowledge with prior experiences, thereby strengthening conceptual relationships. Consequently, reflective practices play a crucial role in fostering meaningful learning and enhancing mathematical reasoning within the PBL framework. (Putri, O. R. U., Susiswo, Hidayanto, E., & Slamet, 2023)

The integration of Deep Learning principles further strengthens the impact of PBL by encouraging students to engage with mathematical concepts at a deeper cognitive level (Anggraini, I. N., et al., 2026). Deep Learning emphasizes understanding, meaning-making, and knowledge transfer rather than surface-level memorization. Within a PBL environment, Deep Learning encourages students to explore the underlying logic of mathematical procedures, analyse relationships among concepts, and apply their knowledge to new situations. Students are challenged to explain the rationale behind their solutions, evaluate alternative approaches, and reflect on the effectiveness of their reasoning (Taufik, Nurtamam, M. E., Dewanto, & Santosa, T. A., 2025). This deeper engagement promotes conceptual understanding and helps students develop a more coherent and interconnected body of mathematical knowledge. As a result, learning becomes more meaningful, durable, and transferable to real-world contexts (Marhaeni, N. H., et al., 2026). Therefore, the combined influence of PBL and Deep Learning creates a powerful educational framework that supports both academic achievement and intellectual growth.

The convergence of evidence from the studies of Glazewski and Cindy E. Hmelo-Silver (2019), John R. Savery (2015), Ashari (2024), and the present study provides a strong theoretical and empirical foundation for the use of PBL in mathematics education. The collective findings consistently demonstrate that students benefit from learning experiences that emphasize investigation, collaboration, reflection, and conceptual understanding (Anggraini, I. N., et al., 2026). These elements not only improve mathematical reasoning but also foster essential twenty-first-century competencies such as critical thinking, communication, creativity, and problem-solving. Given the increasing demands of modern education and the complexity of real-world challenges, instructional approaches that cultivate these competencies are highly valuable. The findings therefore suggest that educators should consider integrating PBL and Deep Learning principles into mathematics instruction to create richer and more meaningful learning experiences. Ultimately, such an approach can help students become independent learners, effective problem solvers, and critical thinkers who are well prepared for both academic success and future professional challenges.

The results of this study also support Deep Learning theory as described by Alt & Boniel-Nissim (2018), who emphasized that instructional approaches focusing on conceptual understanding and interconnection of ideas promote deeper levels of thinking. Their principles

underline that elaboration, reflection, and meaning-making lead to more enduring and substantial learning. Furthermore, findings by Yew & Goh (2016) revealed that PBL significantly enhances students' critical thinking and conceptual comprehension through structured problem-solving processes. (Cuong, L. M., et al., 2025)

Deep Learning is grounded in the belief that effective learning extends beyond the acquisition of factual knowledge and procedural skills. Instead, learners are encouraged to understand underlying principles, recognize relationships among concepts, and apply knowledge in diverse contexts (Suparman, D. J., & Tamur, M., 2021). In the present study, students participating in Problem-Based Learning (PBL) integrated with Deep Learning were continuously challenged to analyse mathematical situations, connect new information with prior knowledge, and construct logical explanations for their solutions. Such learning experiences promoted deeper cognitive engagement and encouraged students to think critically about mathematical concepts rather than relying solely on memorized procedures (Cuong, L. M., et al., 2025). Consequently, students demonstrated stronger mathematical reasoning abilities and a more comprehensive understanding of the subject matter. These findings suggest that instructional practices grounded in Deep Learning principles can significantly contribute to meaningful and sustainable learning outcomes. (Cuong, L. M., et al., 2025)

A central principle of Deep Learning theory is the importance of conceptual understanding as the foundation for long-term learning. According to Alt and Boniel-Nissim (2018), students who focus on understanding relationships among concepts are more likely to develop flexible and transferable knowledge structures. This principle was clearly reflected in the learning activities implemented during the study (Cuong, L. M., et al., 2025). Rather than merely applying formulas to obtain answers, students were encouraged to examine the logic behind mathematical procedures and understand how different concepts were interconnected. Through problem-solving activities, learners identified patterns, explored relationships, and constructed explanations that linked multiple mathematical ideas. Such processes enabled students to develop richer cognitive structures that supported deeper comprehension (Araiza-Alba, P., et al., 2021). As a result, students became more capable of transferring their knowledge to unfamiliar problems and adapting their reasoning to new situations. Therefore, the findings reinforce the argument that conceptual understanding plays a crucial role in the development of mathematical reasoning and higher-order thinking skills. (Cuong, L. M., et al., 2025)

Another important aspect of Deep Learning theory highlighted by Alt and Boniel-Nissim (2018) is elaboration, which refers to the process of extending and enriching understanding through explanation, discussion, and interpretation. In the context of this study, students were encouraged to elaborate on their mathematical thinking by explaining their solution strategies, justifying their conclusions, and discussing alternative approaches with peers. These elaborative activities required learners to organize their thoughts systematically and communicate their reasoning clearly (Araiza-Alba, P., et al., 2021). Through explanation and discussion, students were able to identify gaps in their understanding and refine their conceptual knowledge. Furthermore, elaboration facilitated the integration of new information with existing cognitive frameworks, making learning more meaningful and coherent (Bendo, M. C. D., 2026). The process also encouraged students to evaluate the strengths and weaknesses of different solution methods, thereby enhancing analytical thinking. Consequently, elaboration served as an important mechanism through which Deep Learning contributed to the improvement of mathematical reasoning ability. (Cuong, L. M., et al., 2025)

Reflection represents another key component of Deep Learning theory that was evident in the findings of this study (Bendo, M. C. D., 2026). Reflective thinking enables students to examine their learning experiences critically, evaluate their problem-solving strategies, and consider ways to improve future performance. Throughout the learning process, students were encouraged to reflect on the effectiveness of their approaches and analyse the reasoning behind their solutions (Montejo, D. C., Buscay, C. R., & Nasayao, R. A., 2026). This reflective practice promoted metacognitive awareness, allowing learners to monitor their understanding and regulate their learning more effectively (Bendo, M. C. D., 2026). Reflection also encouraged students to recognize misconceptions and make necessary adjustments to their reasoning processes. As students became more aware of how they learned and solved problems, they developed greater confidence and independence in their mathematical thinking. Therefore, the findings support the proposition that reflection is a vital element in fostering deep and meaningful learning experiences. (Yusuf, A. R., Marji, Sutadji, E., & Sugandi, M., 2023)

The results are further strengthened by the findings of Yew and Karen Goh (2016), who reported that PBL significantly enhances students' critical thinking and conceptual understanding through structured problem-solving processes (Araiza-Alba, P., et al., 2021). Their research suggests that the effectiveness of PBL stems from its ability to engage students in systematic inquiry, analysis, and evaluation while solving authentic problems. Similar patterns were observed in the present study, where students actively participated in analysing mathematical problems, identifying relevant information, and constructing evidence-based solutions (Montejo, D. C., Buscay, C. R., & Nasayao, R. A., 2026). These structured problem-solving experiences encouraged learners to evaluate assumptions, examine alternative strategies, and justify their conclusions logically. Such activities are closely associated with the development of critical thinking and mathematical reasoning skills. Moreover, the collaborative nature of PBL provided opportunities for students to challenge one another's

ideas and refine their understanding through discussion. As a result, students achieved deeper conceptual comprehension and demonstrated improved reasoning performance.

Taken together, the findings of the present study and the supporting evidence from Alt and Boniel-Nissim (2018) as well as Yew and Goh (2016) highlight the complementary relationship between Deep Learning and Problem-Based Learning. Deep Learning provides the theoretical foundation for meaningful understanding through elaboration, reflection, and conceptual integration, while PBL offers a practical instructional framework that facilitates these cognitive processes through authentic problem-solving experiences (Montejo, D. C., Buscay, C. R., & Nasayao, R. A., 2026). The integration of these two approaches creates a powerful learning environment in which students are encouraged to think critically, construct knowledge actively, and develop sophisticated reasoning abilities. Such an environment not only enhances academic performance but also prepares students to apply their knowledge effectively in real-world situations (Amalia, D., et al., 2023). Therefore, the findings reinforce the importance of adopting instructional strategies that promote deep engagement, conceptual understanding, and reflective thinking as essential components of mathematics education.

Problem-based instruction supported by Deep Learning principles is considered effective because it enables students to construct knowledge independently, test ideas through discussion, and justify their solutions. This is supported by Mulyanto et al. (2018), who demonstrated that presenting authentic problems within PBL environments substantially improves mathematical reasoning ability.

Problem-based instruction supported by Deep Learning principles is considered highly effective because it positions students as active participants in the learning process rather than passive recipients of information. Within this instructional framework, students are encouraged to construct their own understanding by investigating problems, exploring alternative solutions, and drawing conclusions based on evidence and logical reasoning (Desramaza, A., et al., 2026). The learning process becomes more meaningful because students are directly involved in discovering knowledge rather than merely receiving explanations from teachers (Ayanwale, M. A., & Omeh, C. B., 2026). Deep Learning principles further strengthen this process by encouraging learners to seek conceptual understanding, make connections among ideas, and reflect on their thinking. As students engage in these activities, they develop a deeper appreciation of mathematical concepts and become more capable of applying their knowledge in different contexts. Such experiences contribute significantly to the development of higher-order thinking skills and mathematical reasoning abilities. Consequently, students become more independent, analytical, and confident in solving mathematical problems. (Mashuri, S., Tahmir, S., Talib, A., & Ihsan, H., 2025)

One of the key strengths of problem-based instruction is its ability to promote independent knowledge construction. In traditional learning environments, students often rely heavily on teachers as the primary source of information. In contrast, problem-based instruction requires learners to identify relevant information, formulate hypotheses, and explore possible solution strategies independently (Fitrah, M., et al., 2025). Through this process, students actively construct meaning and develop a deeper understanding of mathematical concepts (Araiza-Alba, P., et al., 2021). The role of the teacher shifts from being a transmitter of knowledge to a facilitator who guides students' inquiry and supports their learning. This learner-centred approach encourages students to take responsibility for their own learning and develop self-directed learning skills. As students become more actively engaged in constructing knowledge, they gain a stronger sense of ownership over their learning experiences (Indri, I., Musslifah, A. R., Prayitno, H. J., Anif, S., & Adnan, M., 2026). This active engagement ultimately contributes to improved reasoning and problem-solving performance.

Another important advantage of problem-based instruction supported by Deep Learning principles is the opportunity it provides for students to test and refine their ideas through discussion. Collaborative discussions enable learners to share perspectives, compare solution methods, and evaluate the validity of different arguments (Ayanwale, M. A., & Omeh, C. B., 2026). During these interactions, students are challenged to explain their thinking clearly and defend their conclusions using logical and mathematical evidence. Exposure to diverse viewpoints encourages learners to reconsider their assumptions and explore alternative approaches to problem-solving (Fitrah, M., et al., 2025). Such exchanges promote critical thinking and help students develop a more comprehensive understanding of mathematical concepts. Furthermore, discussions create opportunities for peer learning, where students benefit from the insights and experiences of their classmates. Through continuous interaction and dialogue, learners strengthen both their conceptual understanding and their reasoning abilities. (Yusuf, A. R., Marji, Sutadji, E., & Sugandi, M., 2023)

The ability to justify solutions is another critical element that contributes to the effectiveness of this instructional approach (Ayanwale, M. A., & Omeh, C. B., 2026). Mathematical reasoning involves more than obtaining correct answers; it requires students to explain why a particular solution is valid and how conclusions are derived. Problem-based instruction encourages students to provide evidence-based justifications for every step of their reasoning process (Aransado, J. E., 2026). Deep Learning principles reinforce this expectation by emphasizing understanding, explanation, and reflection rather than rote memorization (Araiza-Alba, P., et al., 2021). As students become accustomed to justifying their solutions, they develop stronger logical thinking skills and greater confidence in their mathematical

arguments. This practice also helps learners identify weaknesses in their reasoning and improve the quality of their problem-solving strategies. Consequently, students develop a more rigorous and systematic approach to mathematical thinking. (Hallinger, P., 2021)

The findings of the present study are supported by the work of Mulyanto et al. (2018), who demonstrated that presenting authentic problems within Problem-Based Learning environments substantially improves students' mathematical reasoning ability (Siregar, T., 2025). According to their findings, authentic problems encourage learners to engage in analysis, interpretation, and evaluation, all of which are essential components of mathematical reasoning (Hallinger, P., 2021). When students encounter realistic and meaningful problems, they are required to apply mathematical concepts in ways that mirror real-life situations. This relevance increases motivation and encourages deeper engagement with the learning material. Authentic problems also provide opportunities for students to integrate multiple concepts and develop more sophisticated problem-solving strategies (Fitrah, M., et al., 2025). As a result, learners gain a richer understanding of mathematics and become more proficient in applying logical reasoning to complex situations. These outcomes align closely with the findings of the current study, which revealed significant improvements in students' mathematical reasoning following the implementation of PBL integrated with Deep Learning principles. (Aransado, J. E., 2026)

Taken together, the evidence suggests that problem-based instruction supported by Deep Learning principles offers a powerful approach for enhancing mathematical reasoning and conceptual understanding (Hallinger, P., 2021). By encouraging independent knowledge construction, collaborative discussion, critical reflection, and evidence-based justification, this instructional model creates an environment that supports meaningful learning (Ayanwale, M. A., & Omeh, C. B., 2026). Students are not merely learning mathematical procedures but are developing the capacity to think logically, analyse problems critically, and justify their conclusions systematically (Aransado, J. E., 2026). The support from previous studies, including the findings of Mulyanto et al. (2018), further strengthens the argument that authentic problem-solving experiences play a crucial role in developing mathematical reasoning skills (Hallinger, P., 2021). Therefore, educators seeking to improve students' higher-order thinking abilities should consider integrating Problem-Based Learning and Deep Learning principles into mathematics instruction. Such an approach has the potential to produce learners who are not only academically successful but also capable of applying mathematical reasoning effectively in real-world contexts. (Barana, A., Marchisio, M., & Miori, R., 2019)

The findings confirm that the integration of PBL and Deep Learning has a significant and effective impact on improving students' mathematical reasoning ability. The improvement is evident not only in posttest scores, but also in the quality of students' mathematical arguments, conceptual understanding, and ability to logically connect information. These results reinforce existing empirical evidence that such combined approaches are relevant and promising for enhancing mathematical reasoning at the junior secondary school level, specifically at SMP Negeri 1 Sinunukan, Mandailing Natal Regency, North Sumatra, Indonesia.

4. Conclusion and Suggestions

Based on the results of the study, the implementation of the PBL model integrated with Deep Learning has been proven to significantly improve junior high school students' mathematical reasoning ability at SMP Negeri 1 Sinunukan. The findings show a substantial difference between the pretest and posttest scores, with the posttest results increasing markedly. The significance value of the paired sample t-test ($p < 0.001$) confirms that this learning model is effective in enhancing students' ability to analyze problems, develop strategies, provide logical justification, and understand conceptual relationships within the topic of Systems of Linear Equations in Two Variables (SPLDV). Beyond statistical improvement, classroom observations indicate that students became more engaged in deep thinking processes, group discussions, and reflection; key components of mathematical reasoning.

The N-Gain analysis further demonstrates that the level of improvement in students' mathematical reasoning ability falls within the medium-to-high category (mean N-Gain = 0.64). This indicates that the learning intervention not only improved students' final scores but also strengthened their cognitive processes in understanding concepts, constructing mathematical arguments, and drawing valid conclusions. Students showed greater ability to explain solution steps systematically and displayed deeper conceptual understanding after participating in the learning activities.

Based on these findings, several recommendations can be offered for instructional practice and future research. First, teachers are encouraged to provide an initial explanation of the flow of PBL integrated with Deep Learning so that students clearly understand their roles during exploration, discussion, and problem solving. Such preliminary understanding is essential to prevent confusion and ensure active engagement. Second, effective time management is crucial, as the model requires activities involving analysis, discussion, argumentation, and reflection. Teachers are advised to provide adequate scaffolding, especially during the early stages, to help students gradually develop independent reasoning skills.

Third, future research should consider adapting the context of the problems, the complexity of tasks, and the learning media to match students' characteristics and school facilities. Extending the duration of the learning intervention or increasing the number of meetings may further enhance the model's effectiveness. Fourth, subsequent studies are encouraged to incorporate additional assessment instruments that measure not only cognitive outcomes but also thinking processes, student interactions, and mathematical communication skills through observation sheets, argumentation rubrics, or recorded discussions. Finally, future research may employ experimental designs with control groups or compare the PBL integrated with Deep Learning model with other instructional approaches to obtain a more comprehensive understanding of its effectiveness in mathematics education.

Declarations

Parental Consent Statement: Written informed consent was obtained from the parents or legal guardians of all participating students prior to their participation in the study. Participation was voluntary, and all data were collected, analyzed, and reported anonymously in accordance with institutional ethical guidelines for educational research involving minors.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article. The authors have no financial, personal, or professional relationships that could have influenced the research outcomes or interpretation of the findings.

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Ethical Approval

This study was conducted in accordance with ethical standards for educational research. Permission to conduct the study was obtained from the school administration of SMP Negeri 1 Sinunukan, Mandailing Natal Regency, North Sumatra, Indonesia. The research procedures complied with institutional guidelines for research involving human participants.

Informed Consent

Informed consent was obtained from all participants and relevant school authorities prior to data collection. Participation in the study was voluntary, and participants were informed that their responses would be used solely for research purposes while maintaining confidentiality and anonymity.

Author Contributions

Torang Siregar: Conceptualization, methodology, investigation, data collection, formal analysis, writing—original draft preparation, and manuscript revision.

All authors have read and approved the final version of the manuscript.

Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request. Data are not publicly available due to participant privacy and institutional restrictions.

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Ethics Approval Statement:

This study was reviewed and approved as an exempt educational research study by the institutional ethics committee of UIN Syekh Ali Hasan Ahmad Addary Padangsidimpuan (Reference: FTIK/UIN-SYAHADA/Exempt/2025/01). The study involved the implementation of a standard pedagogical intervention (Problem-Based Learning) in a regular classroom setting at SMP Negeri 1 Sinunukan and utilized non-

invasive, routine educational assessments (pretest/posttest). The research involved no more than minimal risk to participants and did not involve vulnerable populations requiring additional safeguards. All procedures were conducted in accordance with the institutional guidelines for educational research.

References

1. Afifah BA, Imswatama A, Setiani A (2020) Penerapan Model Problem Based Learning untuk Meningkatkan Kemampuan Penalaran Matematis Siswa. De Fermat: Jurnal Pendidikan Matematika 3(1):9–16
2. Aba-Oli Z, Koyas K, Husen A (2025) Higher-order thinking skills-oriented problem-based learning interventions in mathematics: A systematic literature review. School Sci Math 125(3):214–231. https://doi.org/10.1111/ssm.12676
3. Alt D, Boniel-Nissim M (2018) Links between Adolescents' Deep and Surface Learning Approaches, Problematic Internet Use, and Fear of Missing Out (FoMO). Internet Interventions 13:30–39. https://doi.org/10.1016/j.invent.2018.05.002
4. Amalia D, Indiati I, Buchori A, Krisnaningsih G (2023) Promoting mathematics problem solving ability through implementing GeoGebra-assisted problem based learning. UNION Jurnal Ilmiah Pendidikan Matematika 11(2):275–284. https://doi.org/10.30738/union.v11i2.14756
5. Amallya E, Anggoro BS, Fadila A (2025) Problem based learning with geogebra: Impact on mathematical communication skills and mathematical problem solving. LINEAR J Math Educ 6(1):1–13. https://doi.org/10.32332/8g8bjr06
6. Anggraini IN, Dwikoranto D, Lintangesukmanjaya RT, Sukarni S, Marsini M, Khansa IH, Putri NAA (2026) Emerging trends of technology-integrated problem-based learning in physics problem solving: A bibliometric analysis (2015–2025). J Nat Sci Integr 9(1):114–132. https://doi.org/10.24014/jnsi.v9i1.39168
7. Anugraheni I, Gufron A, Purnomo YW (2025) The impact of realistic problem-based learning on mathematical connection abilities: Evidence from elementary schools in Indonesia. Cogent Educ 12(1). Article 2523078. https://doi.org/10.1080/2331186X.2025.2523078
8. Araiza-Alba P, Keane T, Chen WS, Kaufman J (2021) Immersive virtual reality as a tool to learn problem-solving skills. Comput Educ 164:104121. https://doi.org/10.1016/j.compedu.2020.104121
9. Aransado JE (2026) Effectiveness of Technology-Integrated Problem-Based Learning (TIPBL) on Students' Mathematics Performance: A Meta-Analysis. Int J Stud Educ, 640–655
10. Ardhana D, Fajrina S, Fitri R (2025) Implementasi Problem Based Learning berbasis Deep Learning untuk Meningkatkan Berpikir Kritis Siswa pada Materi Sistem Ekskresi di SMA. DUBIOPRENA: Jurnal Ilmiah Pendidikan Biologi 2(2):50–58
11. Ashari NW (2024) Enhancing Mathematical Literacy Through Problem-Based Learning: A Mixed-Methods Analysis of Student Performance. Pedagogy: Jurnal Pendidikan Matematika 9(2):70–77. https://doi.org/10.30605/pedagogy.v9i2.4905
12. Ayanwale MA, Omeh CB (2026) AI-supported problem-based learning for enhancing computational thinking skills in STEM education. Computers Hum Behavior: Artif Hum 7:100263. https://doi.org/10.1016/j.chbah.2026.100263
13. Ayari MA, Sellami A, Santhosh ME, Naji KK, Al-Ali A, Al-Hazbi SMA (2025) From problems to performance: A systematic review of problem-based learning in K–12 mathematics. Front Educ 10:1731307. https://doi.org/10.3389/feduc.2025.1731307
14. Barana A, Marchisio M, Miori R (2019) MATE-BOOSTER: Design of an e-learning course to boost mathematical competence. In *Proceedings of the 11th International Conference on Computer Supported Education* (pp. 280–291). https://doi.org/10.5220/0007721702800291
15. Cuong LM, Tien-Trung N, Ngu PNH, Vangchia V, Thao NP, Thao TTP (2025) Mathematics problem-solving research in high school education: Trends and insights from the Scopus database (1983–2023). Eur J Sci Math Educ 13(2):77–89. https://doi.org/10.30935/scimath/16038
16. Dahal PP,G.C., L (2026) Effectiveness of Project-Based Learning in Enhancing Mathematical Reasoning and Creativity: A Systematic Review. KMC J 8(1):198–212. https://doi.org/10.3126/kmcj.v8i1.90657
17. Desramaza A, Jamaan EZ, Yerizon, Fauzan A (2026) Enhancing Problem-Solving in Junior High School Mathematics and Science Through Guided Inquiry and Deeper Learning: A Systematic Literature Review. Jurnal Penelitian Pendidikan IPA 12(3):105–115. https://doi.org/10.29303/jppipa.v12i3.14861
18. Destini F, Syafridin U, Drupadi R (2026) The Effectiveness of Artificial Intelligence-Assisted Problem-Based Learning Model to Improve Elementary School Students' Mathematical Representation Processing Ability. Bima J Elementary Educ 4(1):13–26. https://doi.org/10.37630/bijee.v4i1.4351

19. Dewi DV, Triwahyuni E, Kustiyowati (2025) Problem-Based Learning Model with Deep Learning Approach on Students' Interests and Problem-Solving Abilities in Vocational High School. Jurnal Ilmiah Pendidikan Profesi Guru 8(2):433–444. https://doi.org/10.23887/jippg.v8i2.102920
20. Fardian D, Dasari D (2023) The effects of problem-based learning on mathematical proficiency: A combined bibliometric analysis and meta-analysis review. J Didactic Stud 1(2):99–113
21. Fendrik M (2021) Pengaruh Pendekatan Realistic Mathematics Education terhadap Kemampuan Penalaran Matematis Siswa SD ditinjau dari Kemampuan Siswa dan Level Sekolah. Numeracy 8:102–112. https://doi.org/10.46244/numeracy.v8i2.1611
22. Feriyanto F, Anjariyah D (2024) Deep Learning Approach Through Meaningful, Mindful, and Joyful Learning: A Library Research. Electron J Educ Social Econ Technol 5(2):208–212. https://doi.org/10.33122/ejeset.v5i2.321
23. Fitrah M, Sofroniou A, Setiawan C, Widihastuti W, Yarmanetti N, Jaya MPS, Panuntun JG, Arfaton A, Beteno S, Susianti I (2025) The Impact of Integrated Project-Based Learning and Flipped Classroom on Students' Computational Thinking Skills: Embedded Mixed Methods. Educ Sci 15(4):448. https://doi.org/10.3390/educsci15040448
24. Glazewski KD, Hmelo-Silver CE (2019) Scaffolding and supporting use of information for ambitious learning practices. Inform Learn Sci 120(1/2):39–58. https://doi.org/10.1108/ILS-08-2018-0087
25. Hallinger P (2021) Tracking the evolution of the knowledge base on problem-based learning: A bibliometric review, 1972–2019. Interdisciplinary J Problem-Based Learn 15(1). https://doi.org/10.14434/ijpbl.v15i1.28984
26. Hallinger P, Nguyen V-T (2020) Mapping the landscape and structure of research on education for sustainable development: A bibliometric review. Sustainability 12(5). https://doi.org/10.3390/su12051947
27. Hasanah U, Pujiastuti H, Keguruan F, Pendidikan I, Sultan U, Tirtayasa A (2023) Analisis Kemampuan Penalaran Matematis Siswa SMP Ditinjau Dari Perbedaan Gender. J-PiMat, 5(1)
28. Indri I, Musslifah AR, Prayitno HJ, Anif S, Adnan M (2026) Ulul Albab–Based Lesson Study in Madrasah Aliyah: A School Action Research on Science and Mathematics Teachers' Pedagogical Transformation. Nazhruna: Jurnal Pendidikan Islam 9(2):350–370. https://doi.org/10.31538/nzh.v9i2.422
29. Kemendikbudristek (2022) Kurikulum Merdeka. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Jakarta
30. Kusuma DC, Amelia R (2018) Meningkatkan Disposisi Matematis Siswa SMP menggunakan Pendekatan Pembelajaran Berbasis Masalah. JPMI (Jurnal Pembelajaran Matematika Inovatif) 1(1):45. https://doi.org/10.22460/jpmi.v1i1.p4552
31. Laine CE, Mahmud MS (2022) The influence of problem-based learning (PBL) on mathematics learning: Systematic literature review. Int J Acad Res Progressive Educ Dev 11(3):922–939. https://doi.org/10.6007/IJARPED/v11-i3/15033
32. Marchy F, Murni A, Kartini, Muhammad I (2022) The effectiveness of using problem-based learning (PBL) in mathematics problem-solving ability for junior high school students. AlphaMath J Math Educ 8(2):185–198. https://doi.org/10.30595/alphamath.v8i2.15047
33. Marhaeni NH, Khuzaini N, Kholis Frendika (2026) Joymath Cognitive Behavioral Intervention to Enhance Numeracy Literacy and Mathematical Resilience at At-Tanzil Learning Center: Intervensi Joymath Cognitive Behavioral dalam Peningkatan Literasi Numerasi dan Resiliensi Matematis di Sanggar Belajar At-Tanzil. Room Civil Soc Dev 5(1):1–12. https://doi.org/10.59110/rcsd.806
34. Martaningsih ST, Maryani I, Prasetya DS, Purwanti S, Sayekti IC, Aziz A, N. A., Siwayanan P (2022) STEM problem-based learning module: A solution to overcome elementary students' poor problem-solving skills. Pegem J Educ Instruction 12(4):340–348. https://doi.org/10.47750/pegegog.12.04.35
35. Mashuri S, Tahmir S, Talib A, Ihsan H (2025) Problem-Based Learning in Mathematics Education: A Bibliometric Analysis of Key Trends and Future Directions in the Last Decade. Educational Process: Int J 18:e2025419
36. McLeod SA Bandura–Social learning theory. Simply Psychology., Muzakkir MA (2016) (2021). An implementation of problem based learning model to improve mathematics solving problem ability of the students class XI MIA SMA Negeri 4 Gorontalo Utara. Jurnal Penelitian Matematika Dan Pendidikan Matematika, 6(1), 45–52. https://doi.org/10.26486/jm.v6i1.2126
37. Montejo DC, Buscay CR, Nasayao RA (2026) Technology-Integrated Problem-Based Learning in Mathematics Education: A Scoping Review of Technological Trajectories, Pedagogy, Learning, and Challenges. Davao Res J 17(1):30–43. https://doi.org/10.59120/drj.v17i1.490
38. Mulyanto H, Gunarhadi G, Indriayu M (2018) The Effect of Problem Based Learning Model on Student Mathematics Learning Outcomes Viewed from Critical Thinking Skills. Int J Educational Res Rev 3(2):37–45. https://doi.org/10.24331/ijere.408454
39. Mutmainnah N, Adrias, Zulkarnaini AP (2025) Implementasi Pendekatan Deep Learning terhadap Pembelajaran Matematika di Sekolah Dasar. Pendas: Jurnal Ilmiah Pendidikan Dasar 10(1):858–871. https://doi.org/10.23969/jp.v10i01.23781
40. Muzakkir MA (2021) An implementation of problem based learning model to improve mathematics solving problem ability of the students class XI MIA SMA Negeri 4 Gorontalo Utara. Jurnal Penelitian Matematika Dan Pendidikan Matematika 6(1):45–52.

https://doi.org/10.26486/jm.v6i1.2126

41. Nasution MS, Elvina E, Safrudin S, Rejeki R (2026) The Effect of the Deep Learning Approach on the Fantasy Story Writing Skills of Fifth-Grade Students. Attadrib: Jurnal Pendidikan Guru Madrasah Ibtidaiyah 9(1):108–118. https://doi.org/10.54069/attadrib.v9i1.1147
42. Nurcahyaning Kusumawardani N, Dewi U (2022) & Pendidikan Pascasarjana Universitas Negeri Surabaya, T. Pengaruh Model Problem Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Siswa Dalam Memecahkan Masalah Matematika. *Jurnal Ilmiah Mandala Education (JIME)*, 8(2), 2442–9511. https://doi.org/10.36312/jime.v8i2.3217
43. OECD (2019) PISA 2018 Results (Volume I): What Students Know and Can Do. OECD Publishing, Paris. https://doi.org/10.1787/5f07c754-en
44. Polat H, Özkaya M (2023) The effect of problem posing-based active learning activities on problemsolving and posing performance: The case of fractions. J Pedagogical Res 7(1):67–81. https://doi.org/10.33902/JPR.202317880
45. Pramasdyahsari AS, Setyawati RD, Aini SN, Nusuki U, Arum JP, Astutik ID, Widodo W, Zuliah N, Salmah U (2023) Fostering students' mathematical critical thinking skills on number patterns through digital book STEM PjBL. Eurasia J Math Sci Technol Educ 19(7) Article em2297. https://doi.org/10.29333/ejmste/13342
46. Putra A, Yulanda Y (2021) Kecemasan Matematika Siswa dan Pengaruhnya: Systematic Literature Review. Didaktika: Jurnal Kependidikan 15:1–14
47. Putri ORU, Susiswo, Hidayanto E, Slamet (2023) Problem-solving: Growth of students' mathematical understanding in producing original solutions. Math Teaching-Research J 15(3):168–189
48. Redhana W (2019) Mengembangkan Keterampilan Abad ke-21 dalam Pembelajaran Kimia. Jurnal Inovasi Pendidikan Kimia 13(1):2239–2253
49. Rindengan RF, Wenas R (2020) Problem based learning in mathematics: From the higher into the lower level of students. In Proceedings of the 4 th Asian Education Symposium (pp. 266–268). Atlantis Press. https://doi.org/10.2991/assehr.k.200513.060
50. Rohmatulloh R, Syamsuri S, Nindiasari H, Fatah A (2022) Analisis Meta: Pengaruh Model Pembelajaran Problem Based Learning (PBL) Terhadap Kemampuan Penalaran Matematis Siswa. Jurnal Cendekia: Jurnal Pendidikan Matematika 6(2):1558–1567. https://doi.org/10.31004/cendekia.v6i2.1395
51. Salmi HS, Thuneberg H, Bogner FX (2023) Is there deep learning on Mars? STEAM education in an inquiry-based out-of-school setting. Interact Learn Environ 31(2):1173–1185. https://doi.org/10.1080/10494820.2020.1823856
52. Samosir CM, Muhammad I, Marchy F, Elmawati E (2023) Research trends in problem based learning in middle school (1998–2023): A bibliometric review. Sustainable Jurnal Kajian Mutu Pendidikan 6(1):46–58. https://doi.org/10.32923/kjmp.v6i1.3237
53. Santos JM (2017) 21st century learning skills: A challenge in every classroom. Int J Emerg Multidisciplinary Res 1(1):31–35. https://doi.org/10.22662/IJEMR.2017.1.1.031
54. Sari YI, Sumarmi, Utomo DH, Astina IK (2021) The effect of problem based learning on problem solving and scientific writing skills. Int J Instruction 14(2):11–26. https://doi.org/10.29333/iji.2021.1422a
55. Savery JR (2015) Overview of Problem-Based Learning: Definitions and Distinctions. Essential Readings in Problem-Based Learning. Purdue University, West Lafayette, pp 5–16. https://doi.org/10.2307/j.ctt6wq6fh.6
56. Shongwe B (2024) The effect of STEM problem-based learning on students' mathematical problemsolving beliefs. Eurasia J Math Sci Technol Educ 20(8) Article em2486. https://doi.org/10.29333/ejmste/14879
57. Sulistiani L, Lusiana L (2024) Penerapan Model Problem Based Learning untuk meningkatkan Kemampuan Penalaran Matematis Peserta Didik Kelas 7 SMP Negeri 10 Palembang. Indonesian Res J Educ 4(3):1244–1250. https://doi.org/10.31004/irje.v4i3.1025
58. Suparman DJ, Tamur M (2021) Problem-based learning for mathematical critical thinking skills: A meta-analysis. J Hunan Univ Nat Sci, *48*(2)
59. Suseelan M, Chew CM, Chin H (2022) Research on mathematics problem solving in elementary education conducted from 1969 to 2021: A bibliometric review. Int J Educ Math Sci Technol 10(4):1003–1029. https://doi.org/10.46328/ijemst.2198
60. Sutama., Faiziyah N, Hidayati YM, Novitasari M, Hanif AR, Adnan M (2026) Deep Learning-Oriented Mathematics Learning: Strengthening Critical Thinking in Junior High School. Educational Process: Int J 22:e2026042. https://doi.org/10.22521/edupij.2026.22.42
61. Taufik, Nurtamam ME, Dewanto, Santosa TA (2025) The Effectiveness of Deep Learning based PjBL on Student's Scientific and Critical Thinking Skills at Indonesia. Jurnal Penelitian Pendidikan IPA 11(9):228–236. https://doi.org/10.29303/jppipa.v11i9.12857

62. Treepob H, Hemtasin C, Thongsuk T (2023) Development of scientific problem-solving skills in grade 9 students by applying problem-based learning. Int Educ Stud 16(4):29–36. https://doi.org/10.5539/ies.v16n4p29
63. Vatillah V, Ambarwati L, El Hakim L (2020) Pengaruh Model Problem Based Learning terhadap Kemampuan Penalaran Matematis dan Self Regulated Learning ditinjau dari Kemampuan Awal Matematika Siswa. Jurnal Penelitian Pembelajaran Matematika 13(2):313–329
64. Wahyudi DA (2025) Pengaruh Pembelajaran Deep Learning terhadap Kemampuan Penalaran Matematis dan Kepercayaan Diri Siswa SMA Dharma Pancasila Medan. Jurnal Inovasi Pendidikan PEDAGOGI 1(1):9–17
65. Yang S, Berdine G (2021) Publication bias in metaanalysis. Southwest Respiratory Crit Care Chronicles 9(41):67–70. https://doi.org/10.12746/swrccc.v9i41.945
66. Yapatang L,fon, Polyiem T (2022) Development of the mathematical problem-solving ability using applied cooperative learning and Polya's problemsolving process for grade 9 students. Journal of Education and Learning, 11(3), 40–46. https://doi.org/10.5539/jel.v11n3p40
67. Yew EHJ, Goh K (2016) Problem-Based Learning: An Overview of its Process and Impact on Learning. Health Professions Educ 2(2):75–79. https://doi.org/10.1016/j.hpe.2016.01.004
68. Yuhana Y, Fajari LEW (2025) Cross-disciplinary effects of problem-based learning on problem-solving skills in mathematics and beyond: A comprehensive meta-analysis and bibliometric. Eurasia J Math Sci Technol Educ 21(11):em2732. https://doi.org/10.29333/ejmste/17345
69. Yusuf AR, Marji, Sutadji E, Sugandi M (2023) Integration of STEM project-based learning into 21st century learning and innovation skills (4Cs) in vocational education using SEM model analysis. Hacettepe Univ J Educ 38(4):454–469. https://doi.org/10.16986/HUJE.2023.499
70. Siregar T (2025) Effectiveness of the Problem-Based Learning Model in Improving Students' Mathematical Communication Skills and Learning Motivation. Preprints. https://doi.org/10.20944/preprints202510.1562.v1
71. Siregar T (2023) A Penerapan Model Pembelajaran Problem-Based Learning Untuk Meningkatkan Prestasi Belajar Matematika Siswa Di SMA Negeri 1 Sinunukan. COMPETITIVE: J Educ 2(2):94–102. https://doi.org/10.58355/competitive.v2i2.9
72. Siregar T (2025) Implementation of Problem-Based Learning (PBL) Model to Enhance Higher-Order Thinking Skills (HOTS). *Available at SSRN 5709306*
73. Siregar T (2025) The Effect of Problem-Based Learning and STEM-Based E-Modules on Students' Mathematical Problem-Solving Skills. *The Effect of Problem-Based Learning and STEM-Based E-Modules on Students' Mathematical Problem-Solving Skills (November 15, 2025)*
74. Bendo MCD (2026) Attention Fragmentation in Digital Learning Environments: Micro-Procrastination, Cognitive Load, and Deep Work Across Educational Levels. J Res Innov Strategies Educ (RISE) 3(6):1–16. https://doi.org/10.70148/rise.v3i4.1

Figures

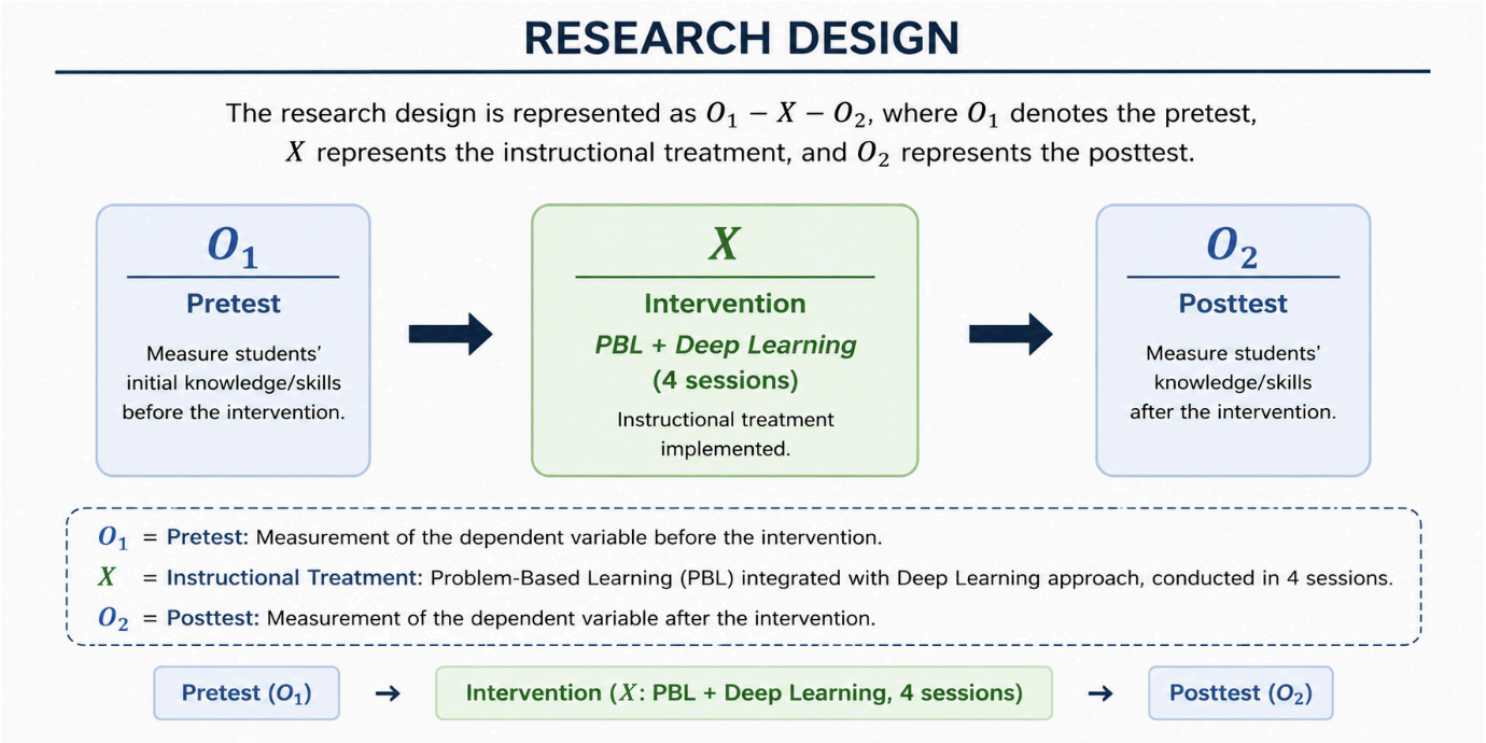

Figure 1

One-Group Pretest–Posttest Design

Pretest (**O_1**) → Intervention (**X: PBL + Deep Learning, 4 sessions**) → Posttest (**O_2**)

Supplementary Files

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